

**Land surface albedos from Land SAF (MSG), CYCLOPES
(VEGETATION/AVHRR) and POLDER/ADEOS projects:
an accuracy assessment based on product inter-comparison and
validation with in situ measurements**

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On-going projects ...



CYCLOPES

February 2003 – January 2006 (2007 ?)
(funded by European Union)

Fusion of data/products (albedo, LAI, fraction of vegetation, fPAR) of several wide FOV optical sensors (period 1997 → 2003).

Version 1 (May 2004) – Version 2 (April 2005)



SAF (Satellite Application Facilities) on Land Surface Analysis
June 1999 – December 2004 (Research & Development)
January 2005 – February 2007 (Initial Operational Phase)
(funded by EUMETSAT & National Meteorological Services)

Implementation of an operational ground segment for near-real time dissemination of land surface parameters in combining Meteosat Second Generation (MSG) and EUMETSAT Polar System (EPS)
Version 1.0 (started on October 12, 2004)



To exploit complementarity between observing systems

	spatial resolution	temporal resolution	spectral channels	observation angles	illumination angle	data availability
version 1	POLDER :	6km	~1 day	5	variable	~constant 1997, 2003
	VGT :	1km	~1 day	4	variable	~constant 1998-
	AVHRR :	4km	~1 day	4	variable	~constant 1982-
	SEVIRI :	3km	15 min	3	constant	variable 2003-2018+
	MERIS :	1km	~2 days	15	variable	~constant 2002-



Version 2

- **POLDER / ADEOS-1 & 2**

Nov 1996 - June 1997, April - Oct 2003: 8 km global, 10-days

- **AVHRR / NOAA**

1999/2000/2002/2003: 8 km global, 10-days

- **MERIS / ENVISAT**

2003 : 8 km / 1 km over Europe and Africa , 10-days

- **VEGETATION / SPOT-4 & 5**

2002 / Jan - Sep 2003: 8 km global / 1 km over Europe and Africa , 10-days

1999: 8 km global North Hemisphere , 10-days



The 4 dimensions of the product fusion

- Observations are available at different sun-view geometries
⇒ *Angular fusion (use of BRDF model of Roujean et al.)*
- Sensors observe in different spectral bands
⇒ *Spectral fusion (use of SAIL code + Xs libraries)*
- Data are not concomitant
⇒ *Temporal fusion (10-days composite period)*
- Projection grid and spatial resolutions are different
⇒ *Spatial fusion (finest resolution to be kept)*

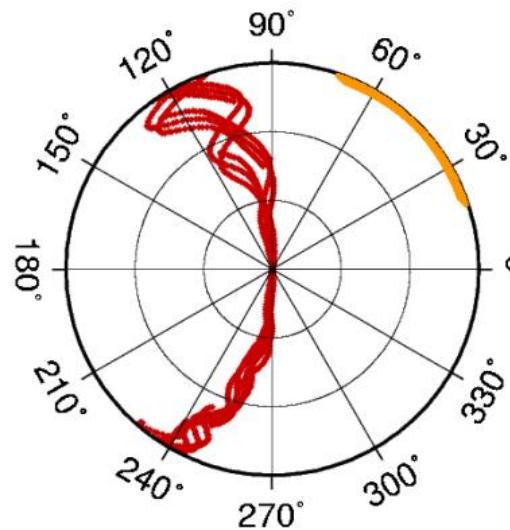


BRDF sampling

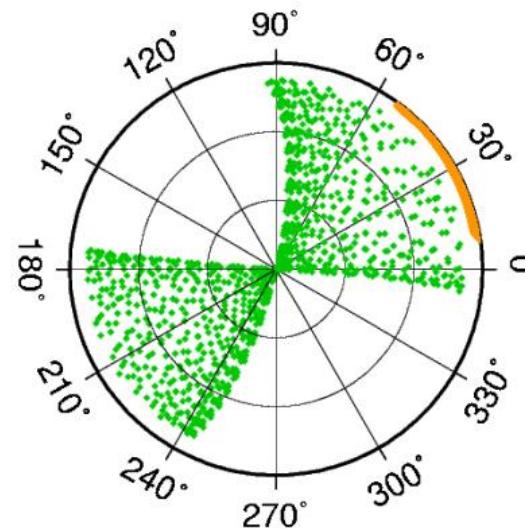
r = Angle zenithal de visee (0-60) ; theta = Azimut relatif

Arc orange = Angle zenithal solaire

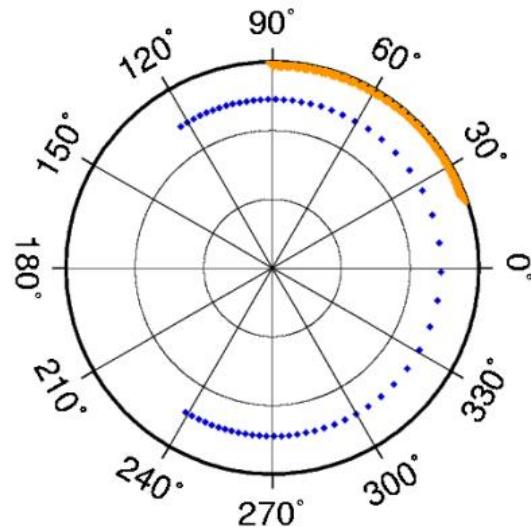
VGT



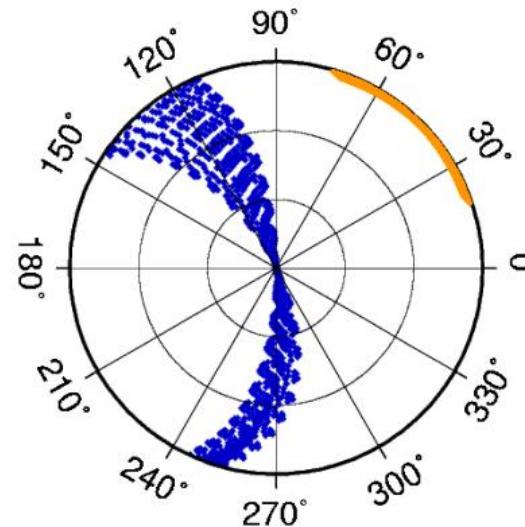
AVHRR



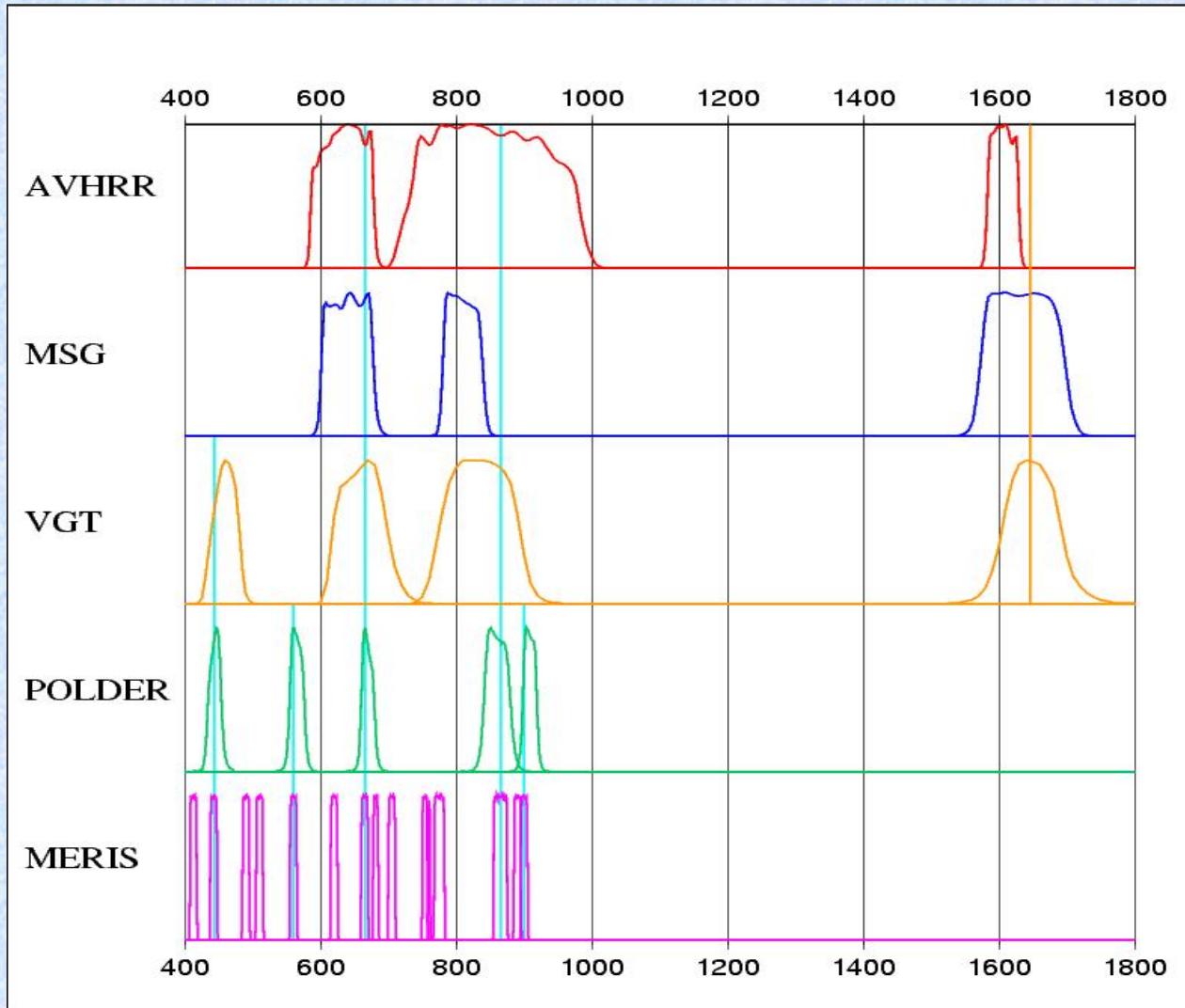
MSG



MERIS



Spectral Normalization



**5 spectral
albedo products
(use MERIS bands
as reference)**

- 445 nm (blue)
- 560 nm (green)
- 665 nm (red)
- 855 nm (NIR)
- 1644 nm (MIR)

**3 broadband
albedo products**

- Visible
- NIR
- Total



COMPARISON WITH BSRN NETWORK DATA SETS

(*Baseline Surface Radiation Network*)

Selected sites

Payerne	Switzerland	BSRN
Toravere	Estonia	BSRN
Espirra	Portugal	Fluxnet
Evora	Portugal	Fluxnet
Tamanrasset	Algeria	BSRN
De Aar	South Africa	BSRN
Solar Village	Saudi Arabia	BSRN

Characteristics

High frequency measurements (each 1 or 3 minutes) of down-welling and up-welling solar fluxes (in clear and partially cloudy situations)

Standard instrumentation in Kipp & Zonen (CM11 & CM21) and Eppley

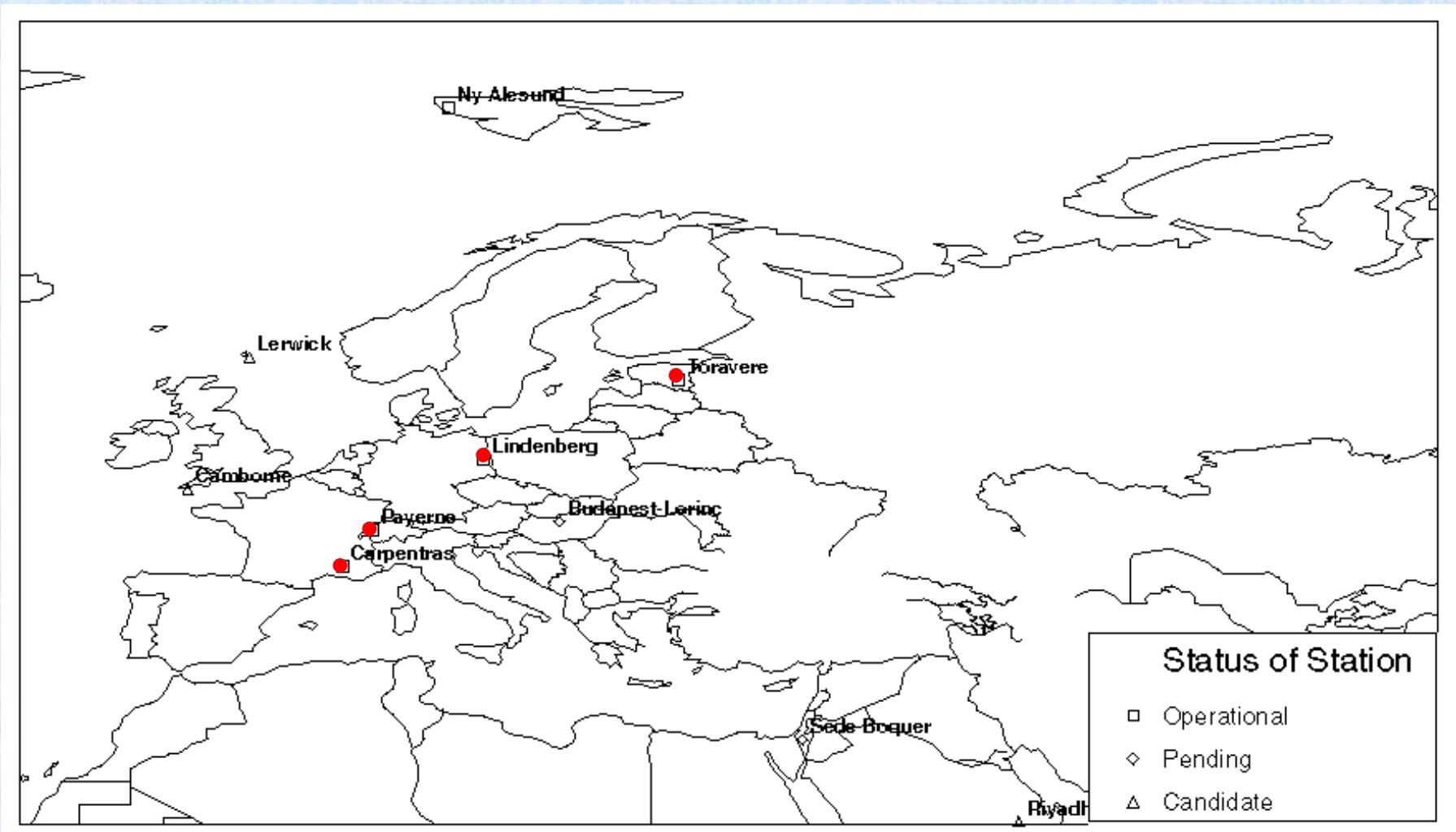
-→ only validation of broadband albedo

Ancillary measurements at sites: diffusion radiation, nebulosity, turbidity



4 BSRN stations in Europe

(Located in various climatic environments)





Validation of broadband albedo

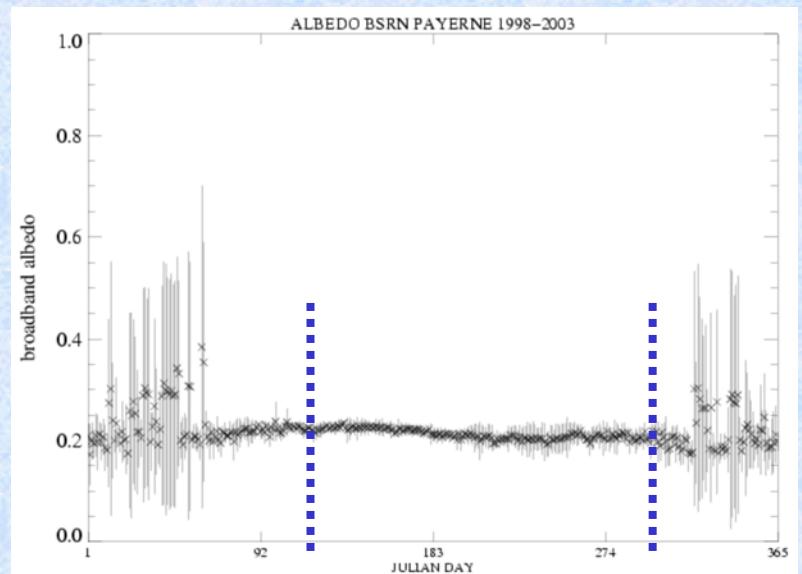
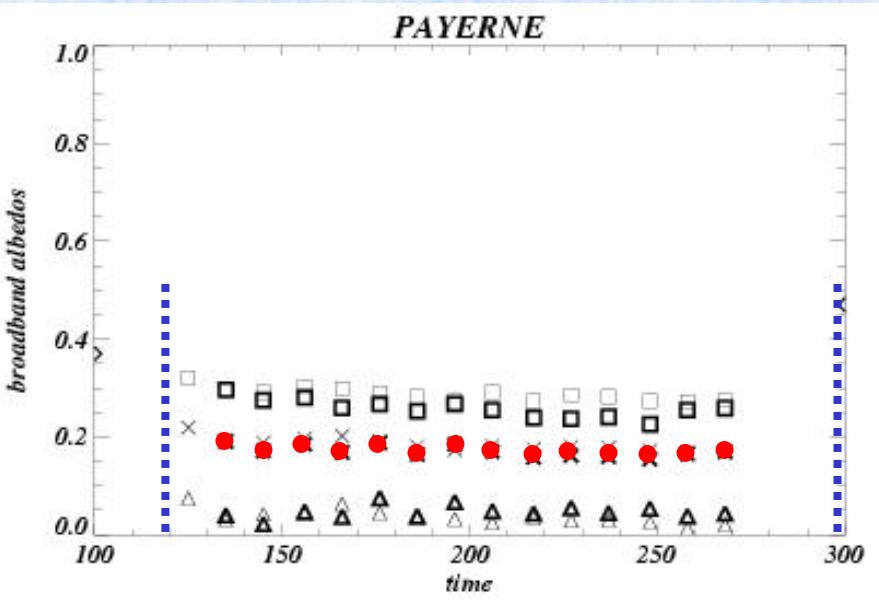
(PAYERNE, Switzerland)

Albedo_1km_V1.0_VGT1_2002

Albedo_1km_V1.0_VGT2_2003 (gras)

BSRN

1998-2003 (yearly average)



Δ: BBBHA_VIS

□ : BBBHA_NIR

● : BBBHA

x

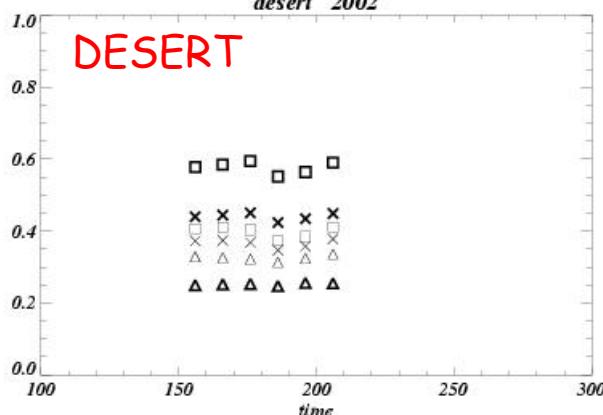
2002

2003



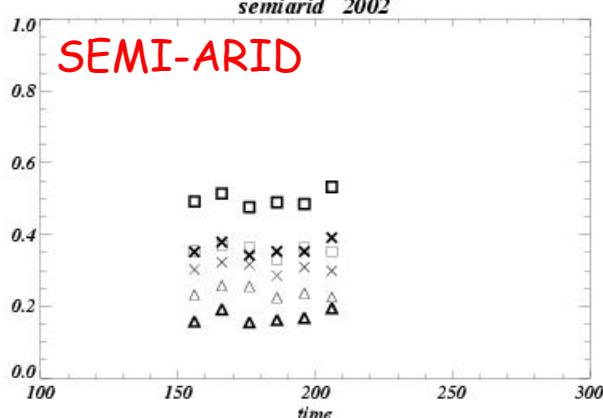
desert 2002

BBBHA



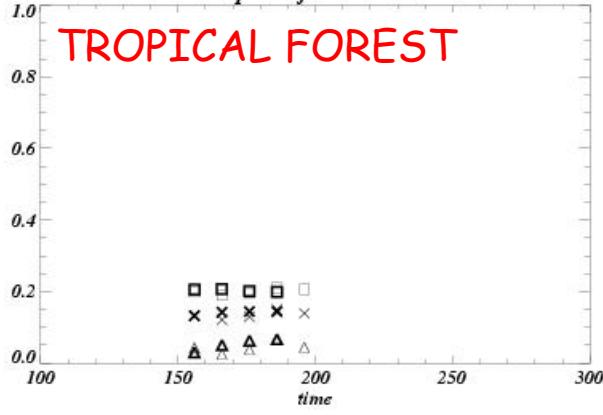
semiarid 2002

BBBHA

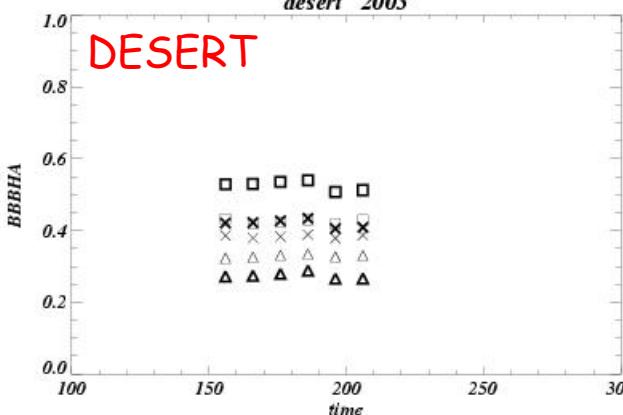


tropical-forest 2002

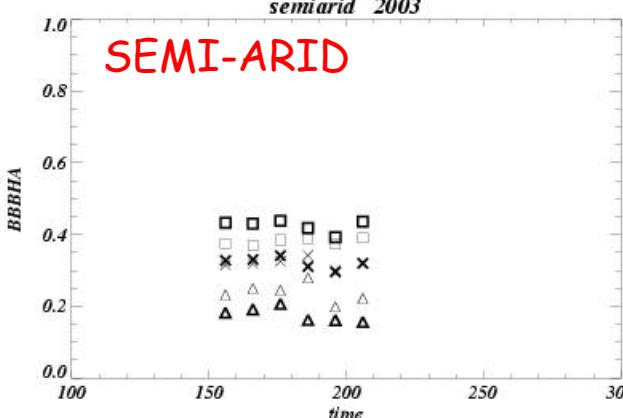
BBBHA



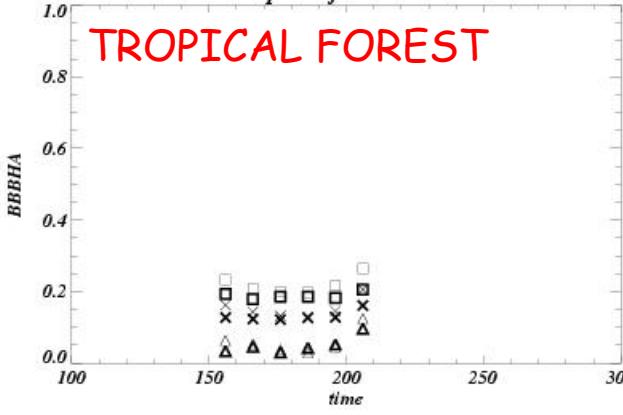
desert 2003



semiarid 2003

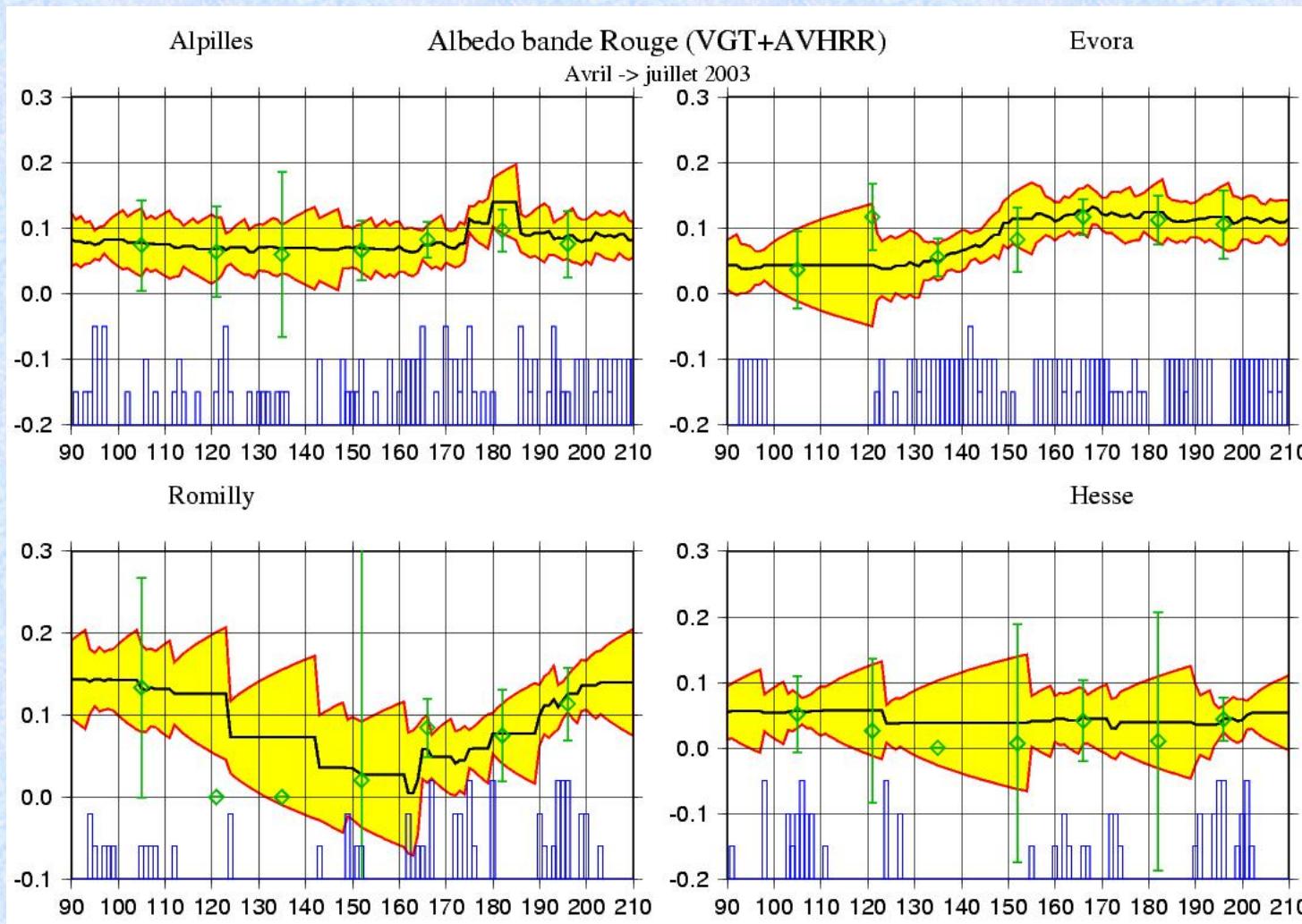


tropical-forest 2003

**Δ : BBBHA_VIS****□ : BBBHA_NIR****X : BBBHA****Pixel = 8 km****AVHRR (*bold*)****VGT**

Comparing inversion methods (temporal scale)

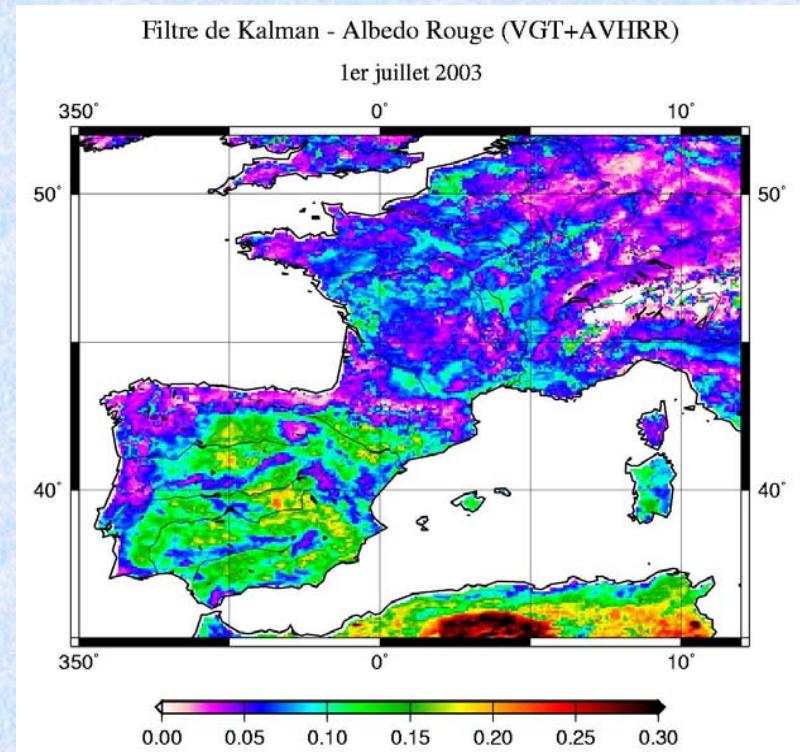
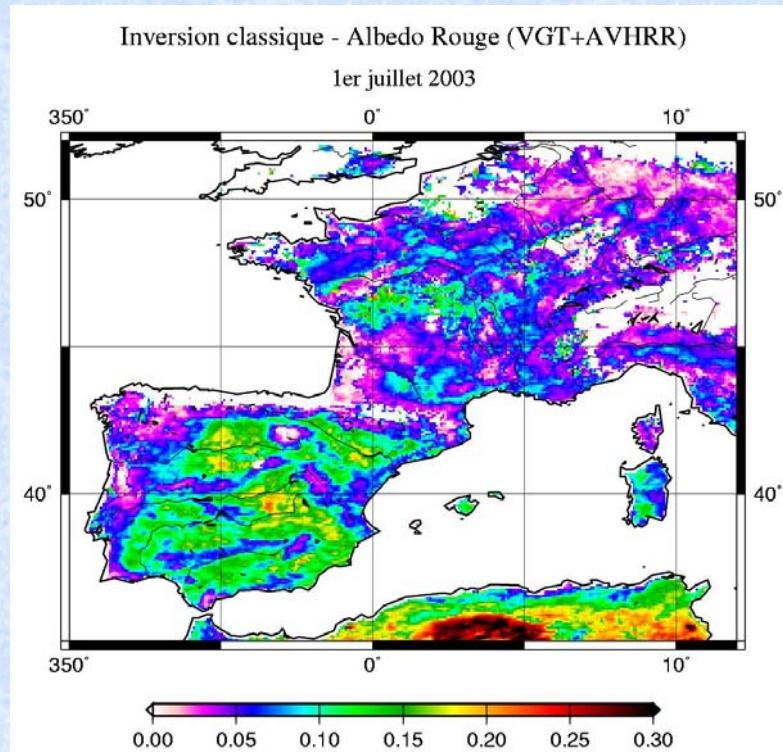
RED band



'Classical'
Inversion
(green)

Kalman
filter
(yellow)

Comparing inversion method (spatial scale)



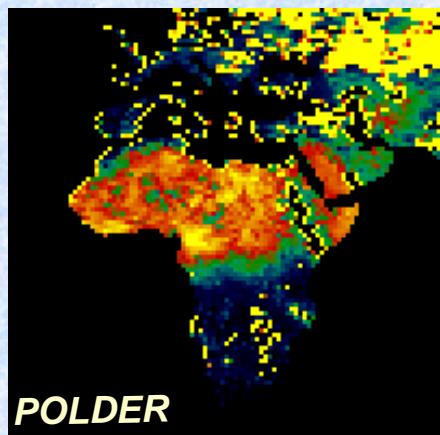
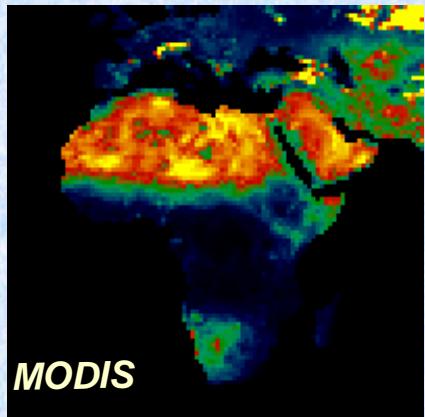
'Classical' inversion

Kalman filter

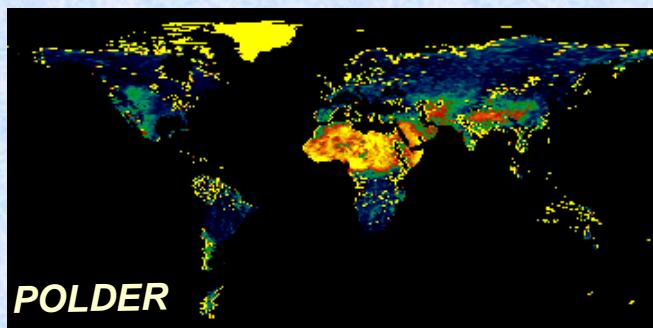
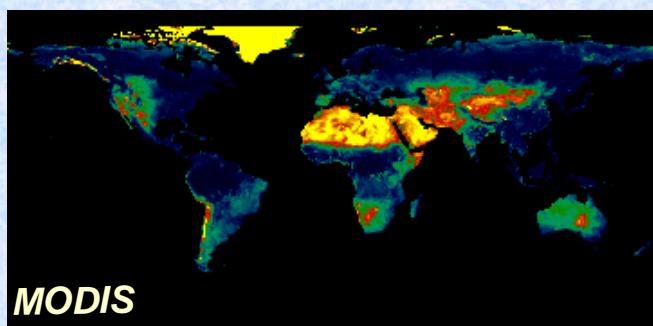
(from O.Samain)

Comparison between MODIS & POLDER (August 15, 2003)

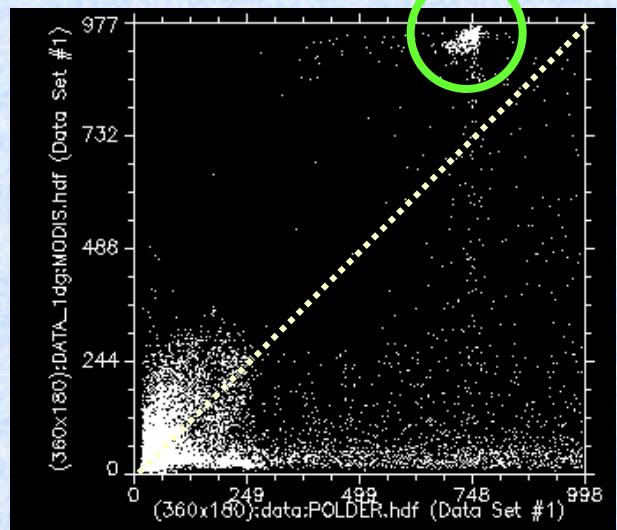
(*VISIBLE Black-Sky Albedo at 1 dg resolution*)



.0 .05 .10 .15 .20 .25 .30 .35



MODIS



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POLDER

Satellite Application Facilities (SAF) on Land Surface Analysis

Institute for
Agrometeorology and
Environment Analysis
Applied to Agriculture

Institute for
Applied
Science and
Technology

University of
Aegean

Federal
Institute of
Hydrology

Meteo-France

University of Valencia



Instituto para Agrometeorología e Hidrología Ambiental
aplicada a la Agricultura
Institute of Agrometeorology and Environmental
Analysis for Agriculture



SMHI

Swedish Meteorological and
Hydrological Institute

Finnish Meteorological Institute



Universidade de Évora



Applied Meteorology
Foundation



Meteorological
Institute of
University of
Bonn



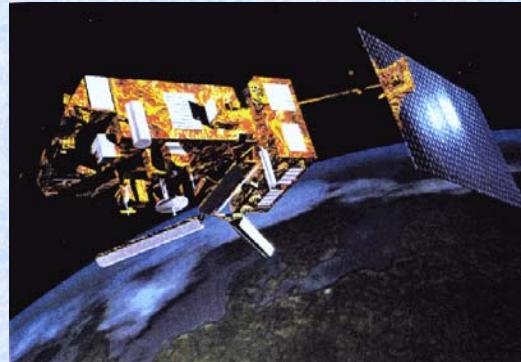
Royal Meteorological
Institute



Institut für Meteorologie und Klimaforschung
Institute of Meteorology and
Climate Research

OBJECTIVES

The main purpose of the Land SAF is to increase the benefits from MSG/SEVIRI and EPS/AVHRR-3 data related to land, land-atmosphere interactions and biophysical applications, namely by developing techniques, that will allow a more effective use of data from the two planned EUMETSAT satellites (MSG and EPS)

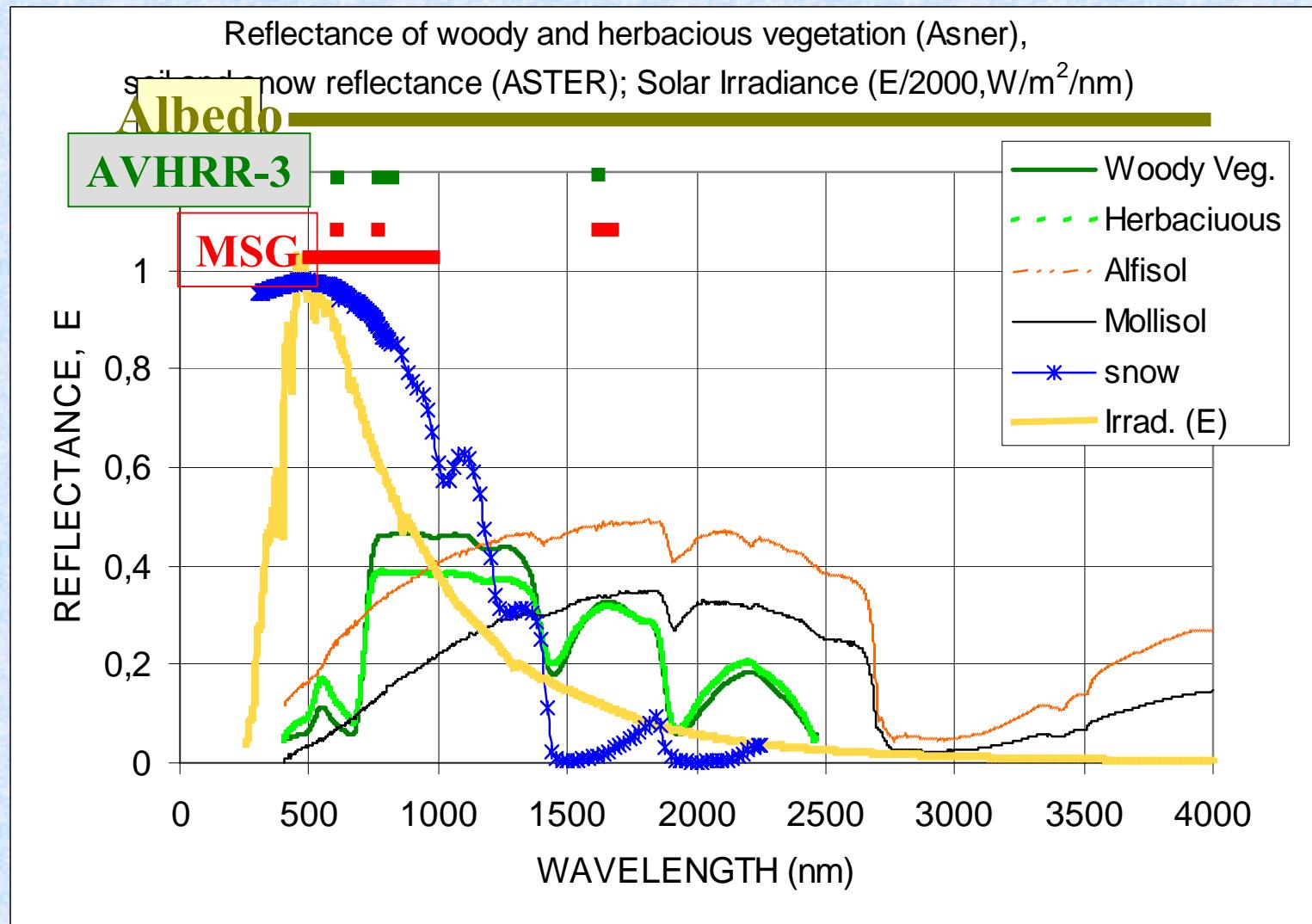


MSG/SEVIRI CHANNELS

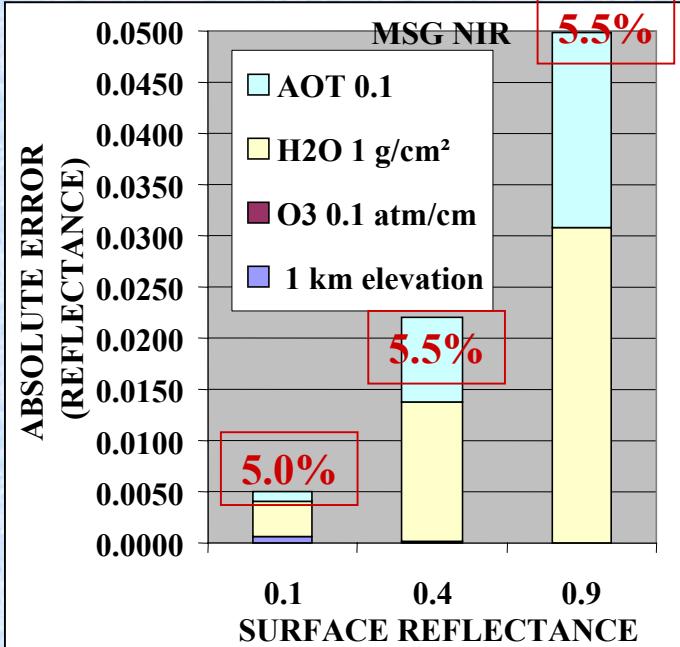
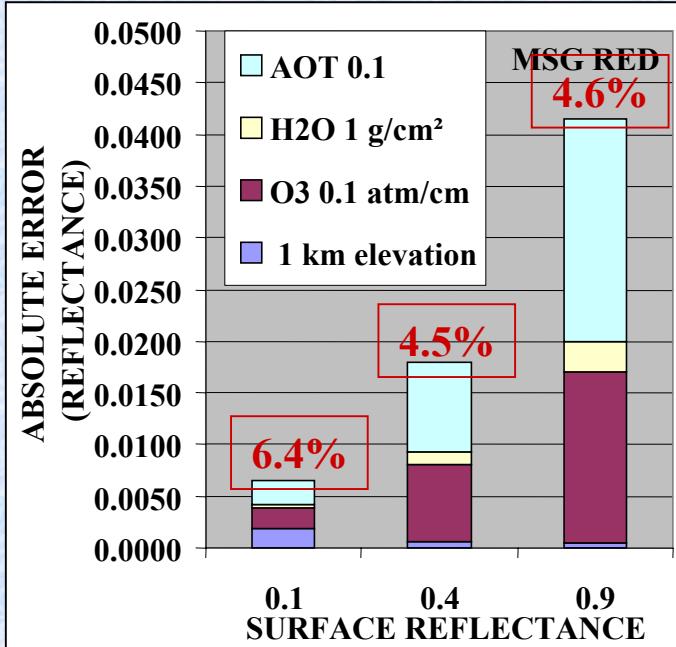
Basic + Airmass + Hi Res Vis Missions

Basic	Band (μm)	Airmass	Band (μm)
VIS 0.6	0.56 - 0.71	WV 6.2	5.35 - 7.15
VIS 0.8	0.74 - 0.88	WV 7.3	6.85 - 7.85
		IR 8.7	8.30 - 9.10
IR 1.6	1.50 - 1.78	O ₃ 9.7	9.38 - 9.94
IR 3.9	3.48 - 4.36	CO ₂ 13.4	12.40 - 14.40
IR 10.8	9.80 - 11.80	High Res VIS	1km Sampling
IR 12.0	11.00 - 13.00	HRV	0.6 - 0.9

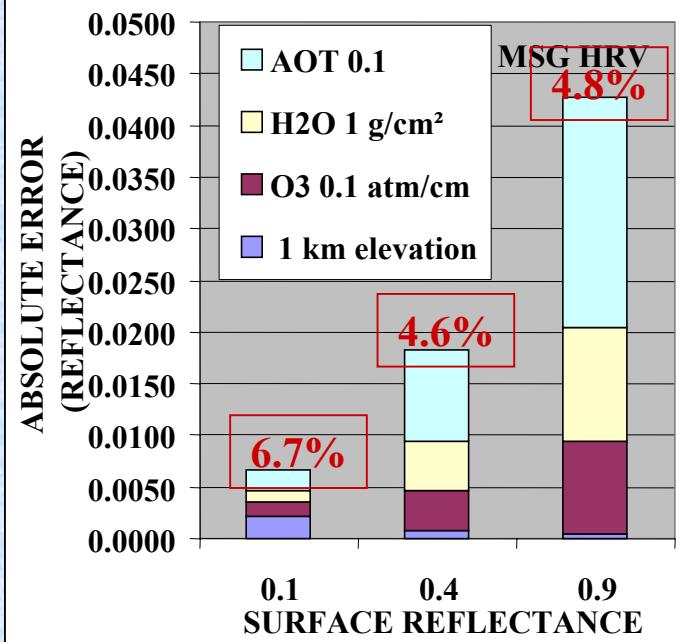
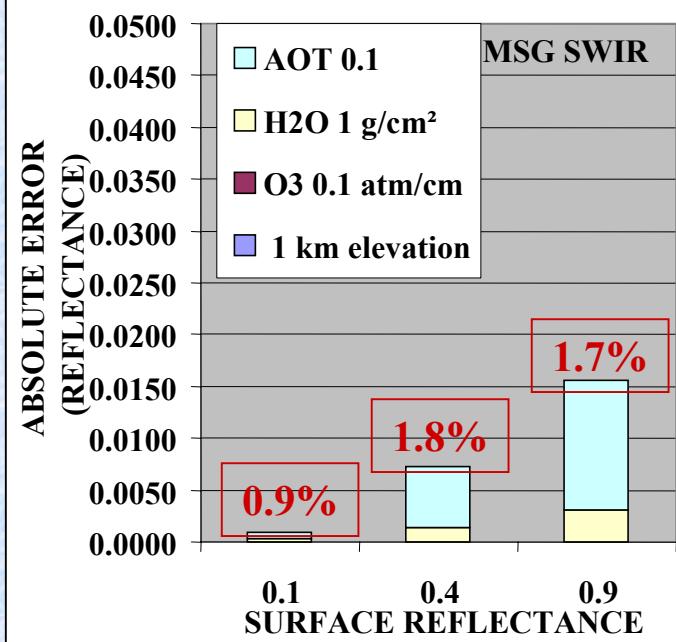
Spectral to Broadband Albedo Conversion



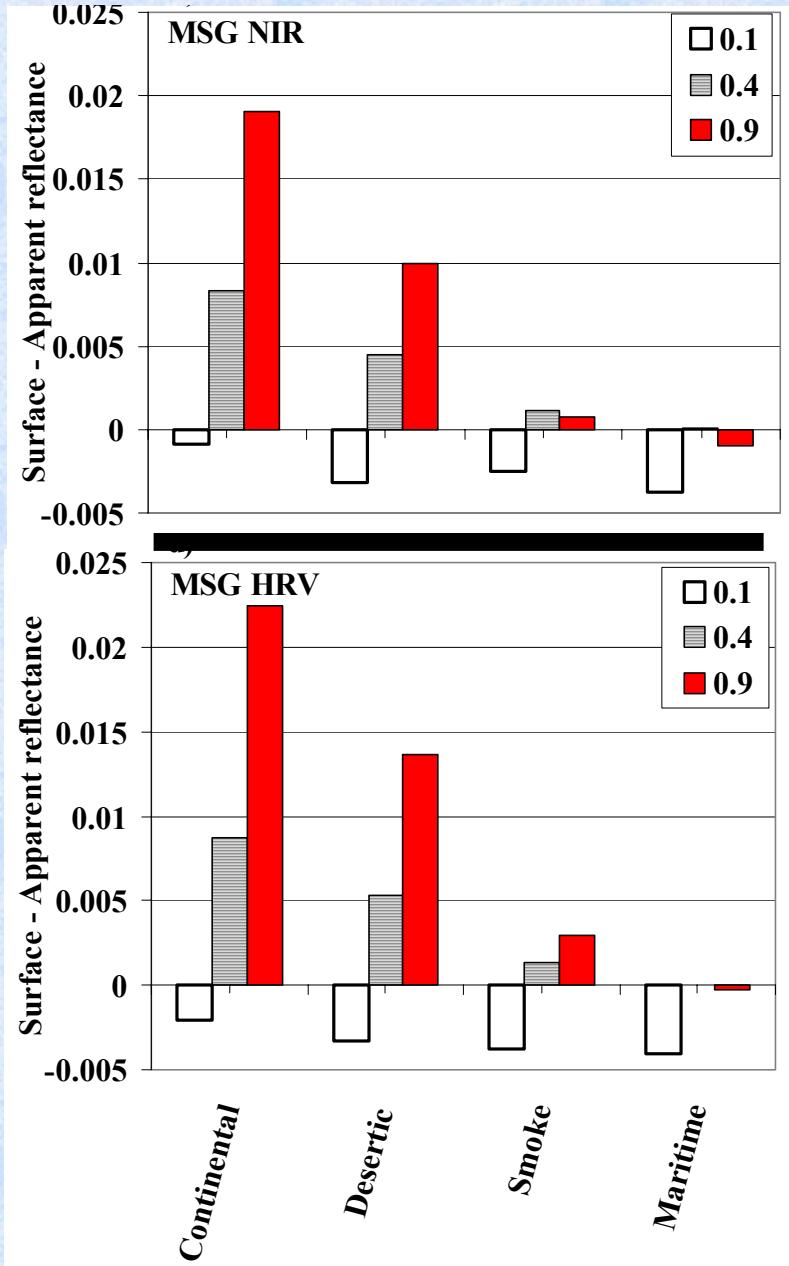
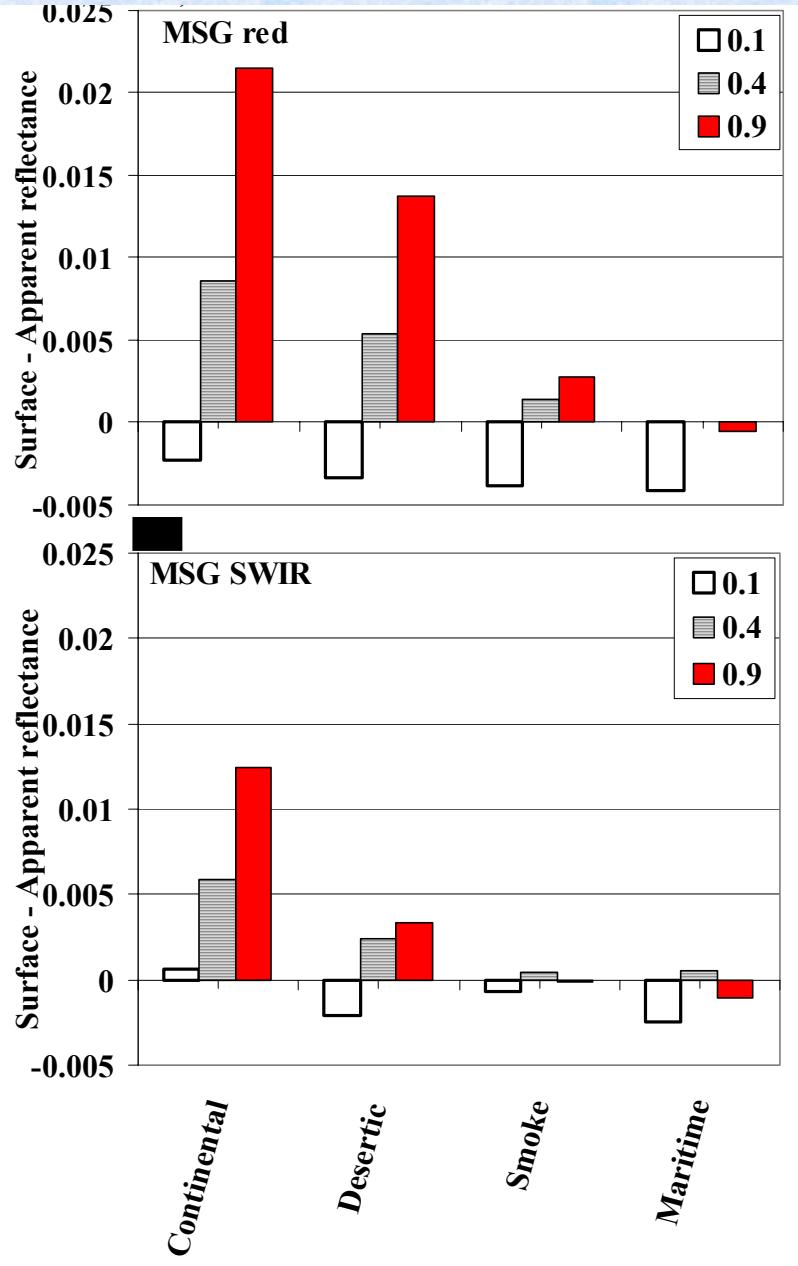
MSG Atmospheric uncertainty



Relative error (%)



Aerosol type effects (0.1 error in AOT)



Theoretical accuracy assessment for surface Albedo



MSG

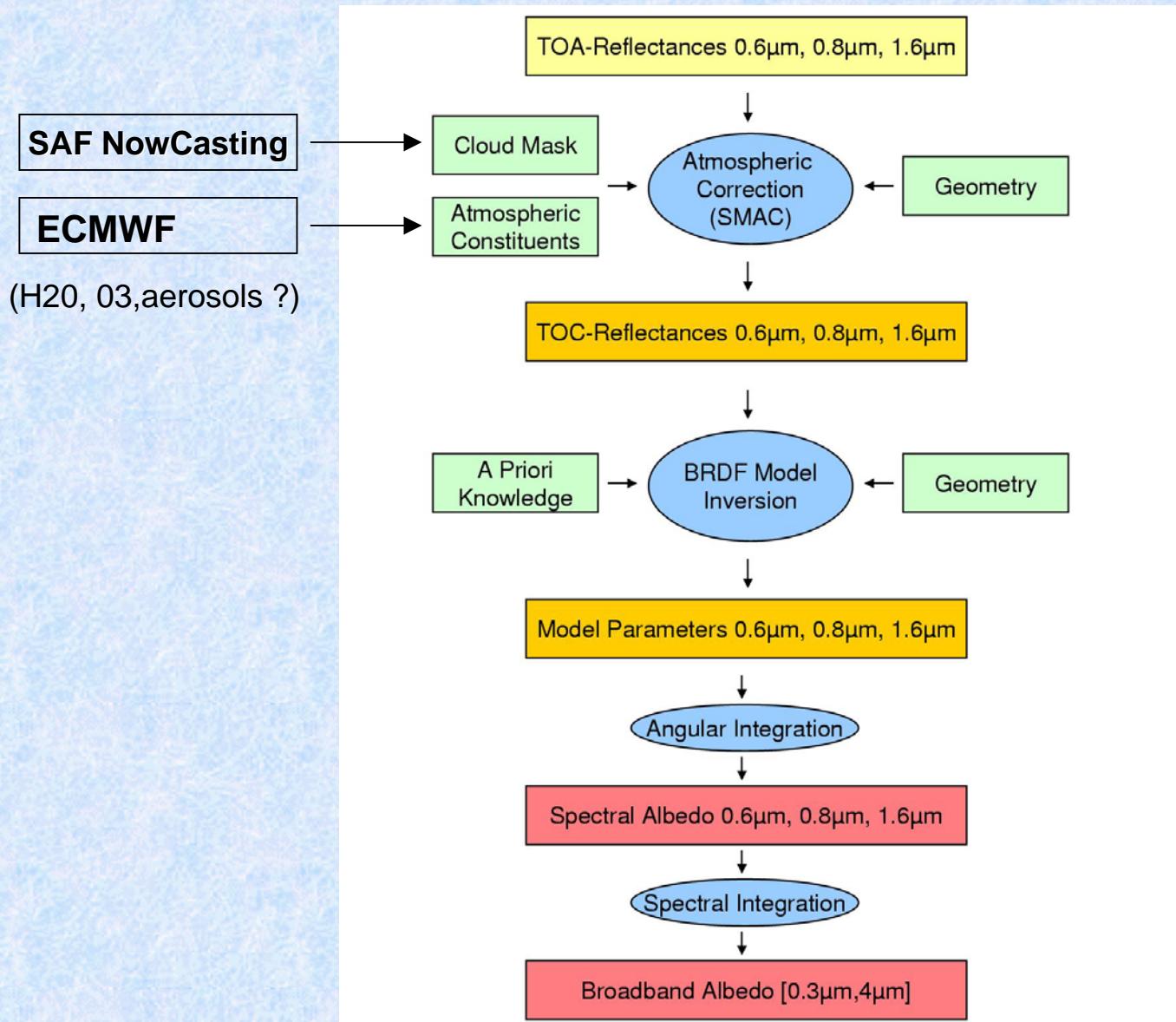


AVHRR-3

Uncertainty (u)	red	NIR	SWIR	HRV	red	NIR	SWIR	
Transfer	0.5%	2.0%	0.7%	1.9%	0.5%	2.0%	0.7%	
Sampling	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	
Cloudmask	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	
Calibration	5%	5%	5%	5%	5%	5%	5%	
Atmosphere	4.5%	5.5%	1.7%	4.6%	4.9%	6.3%	1.6%	
$u_c(A_\lambda)$ range	6.8-15.7%	7.7-16.1%	5.3-15.1%	7.1-15.8%	7.0-15.8%	8.2-16.4%	5.2-15.1%	
Broadband Conversion	~1%				~1%			
<u>$u_c(A_{300-4000})$ range</u>	<u>4.4 - 9.8%</u>				<u>4.6 - 9.9%</u>			

$$u_c^2(A_{300-4000}) = w_{\text{red}}^2 u^2(A_{\text{red}}) + w_{\text{NIR}}^2 u^2(A_{\text{NIR}}) + w_{\text{SWIR}}^2 u^2(A_{\text{SWIR}}) + u^2(\text{sbc})$$

Data processing chain

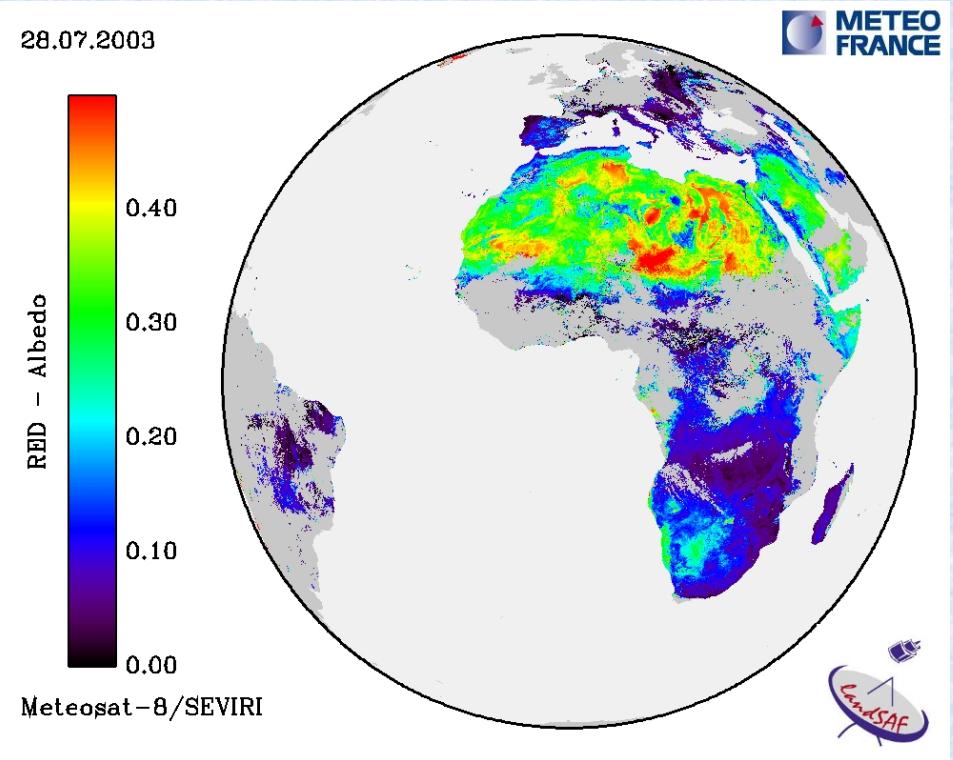


Albédo 0.6 μ m

(prototyping algorithm)

MSG

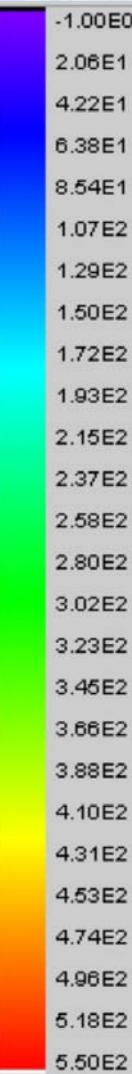
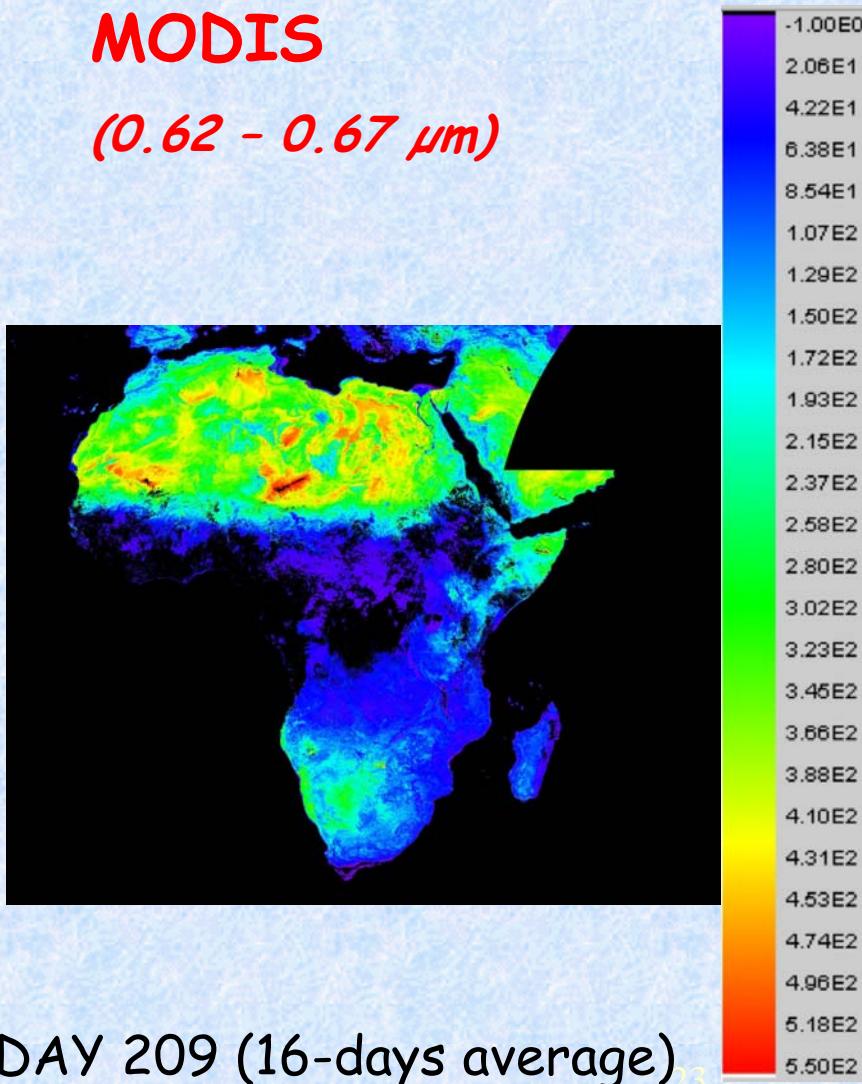
(0.56 - 0.71 μ m)



28/07/2003

MODIS

(0.62 - 0.67 μ m)

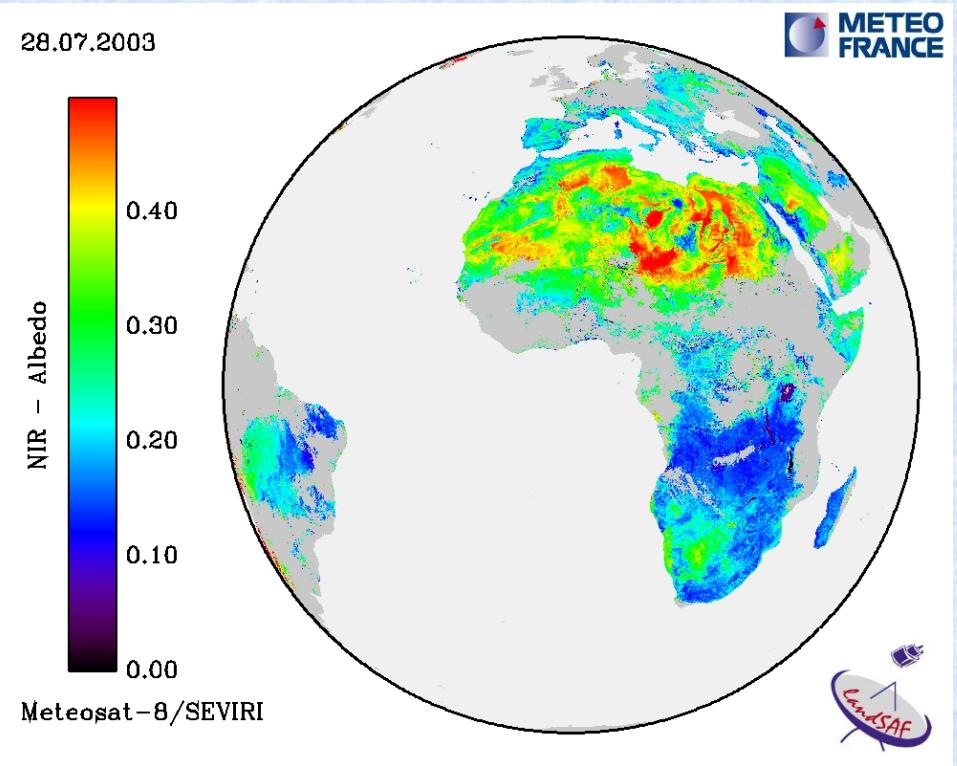


Albédo 0.8 μ m

(*prototyping algorithm*)

MSG

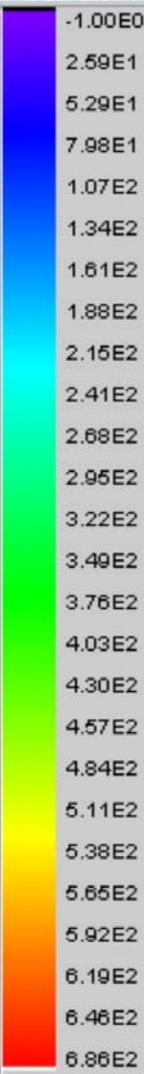
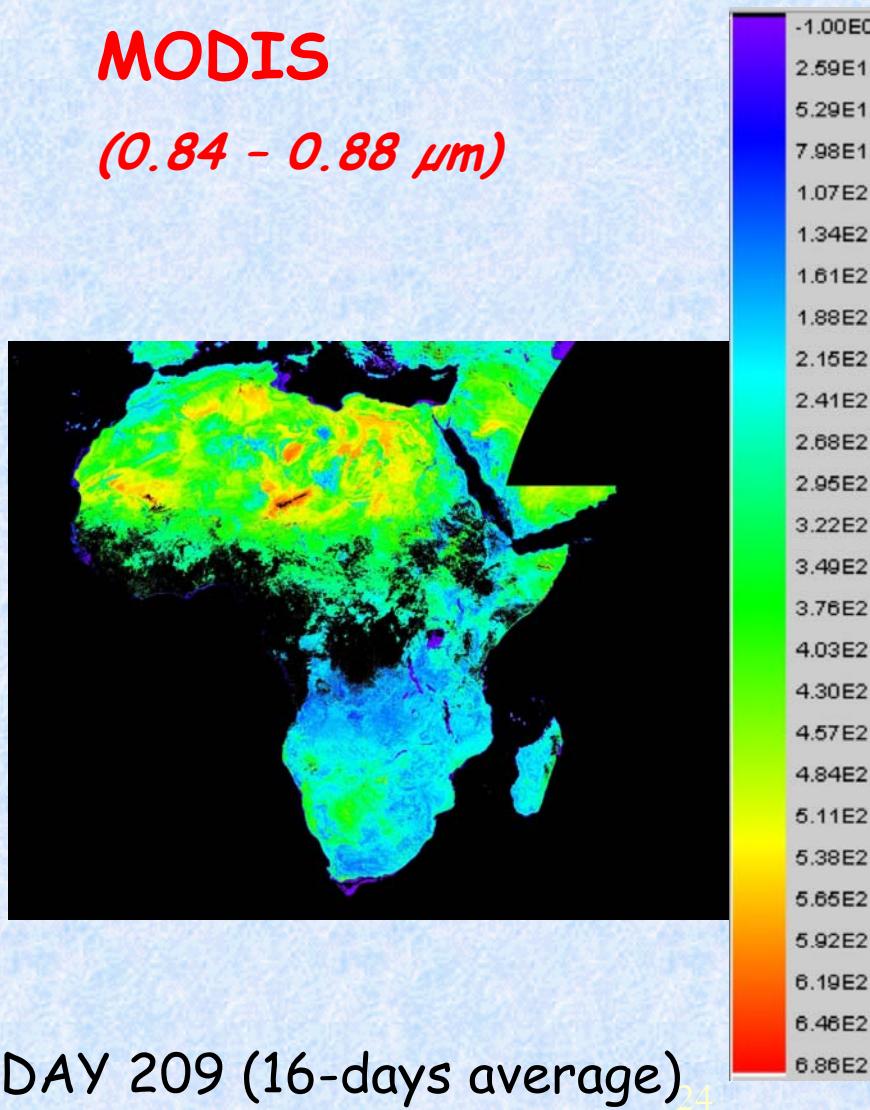
(0.74 - 0.88 μ m)



28/07/2003

MODIS

(0.84 - 0.88 μ m)

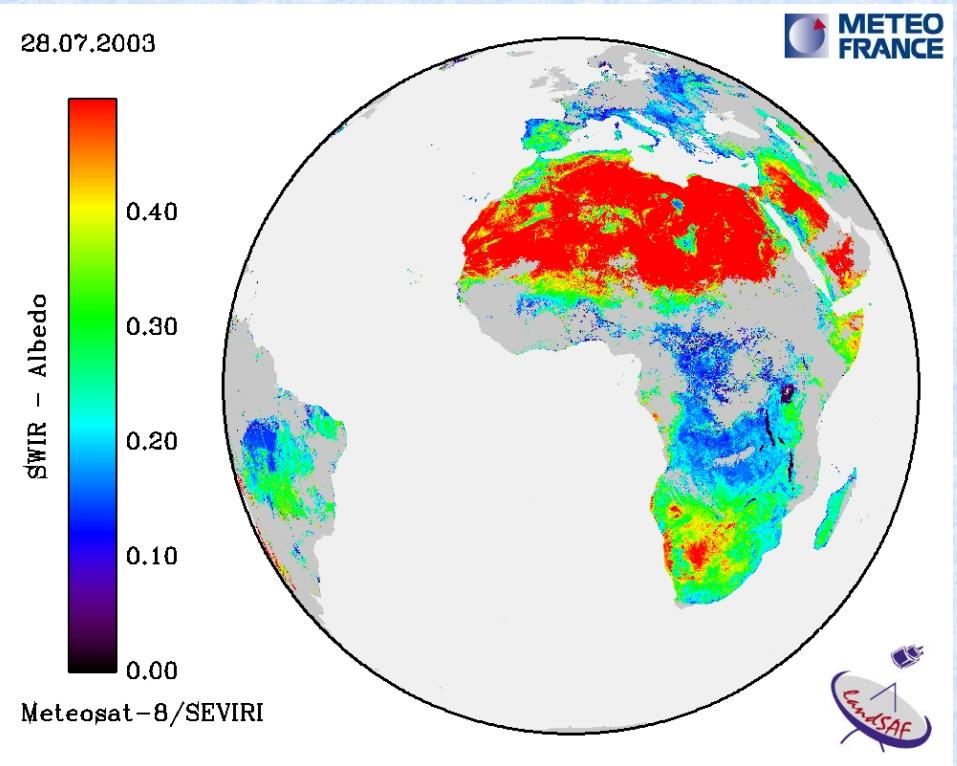


Albédo 1.6 μ m

(*prototyping algorithm*)

MSG

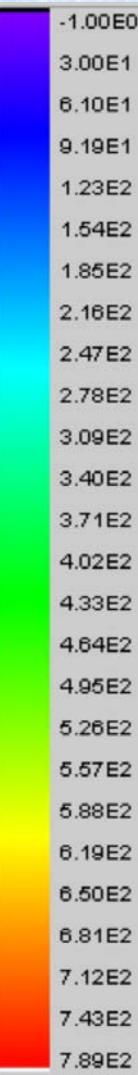
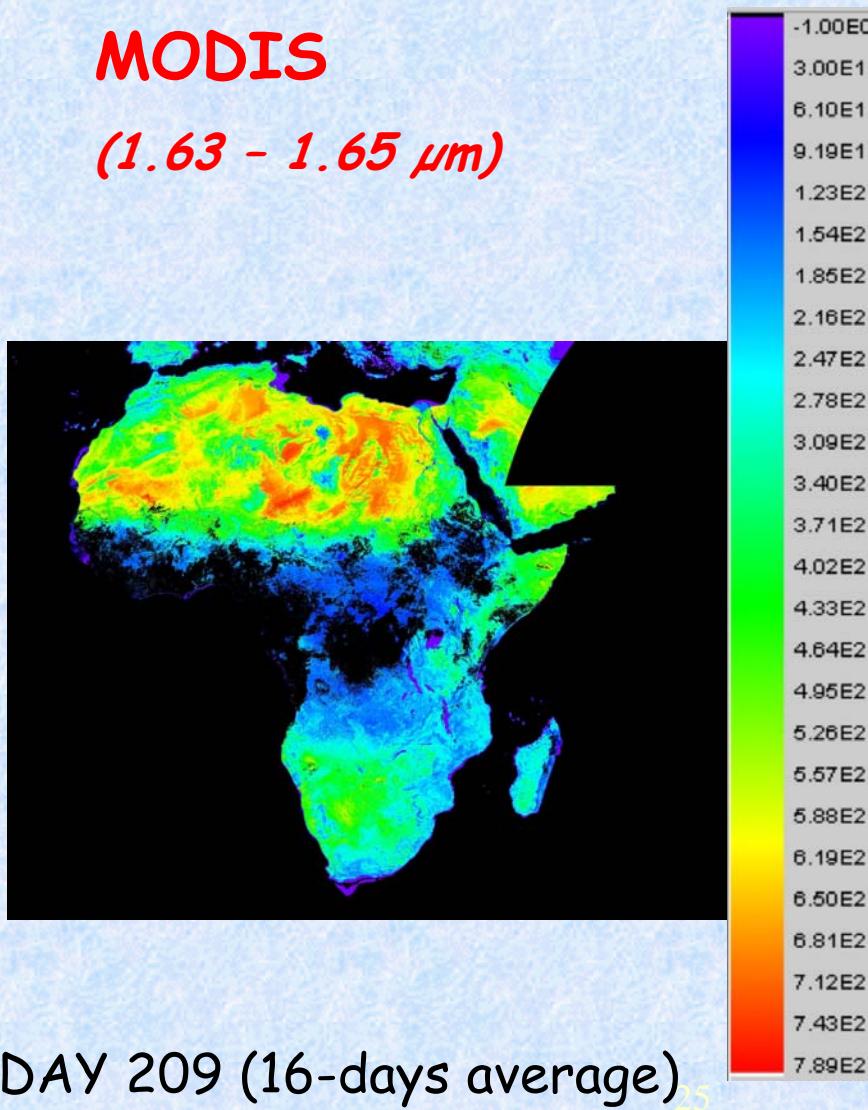
(1.50 - 1.78 μ m)



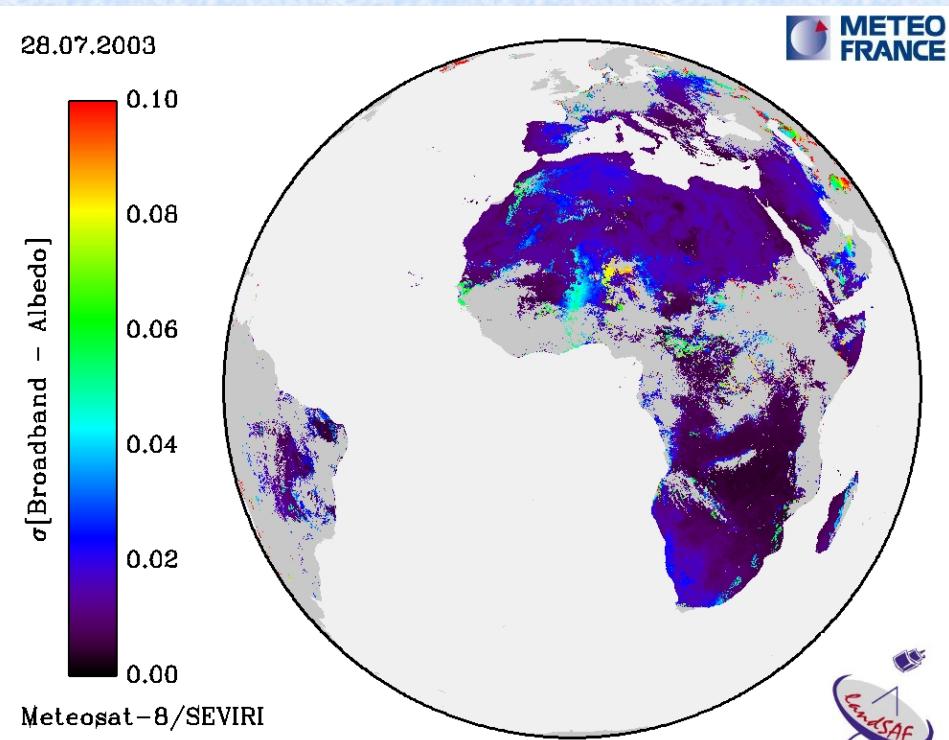
28/07/2003

MODIS

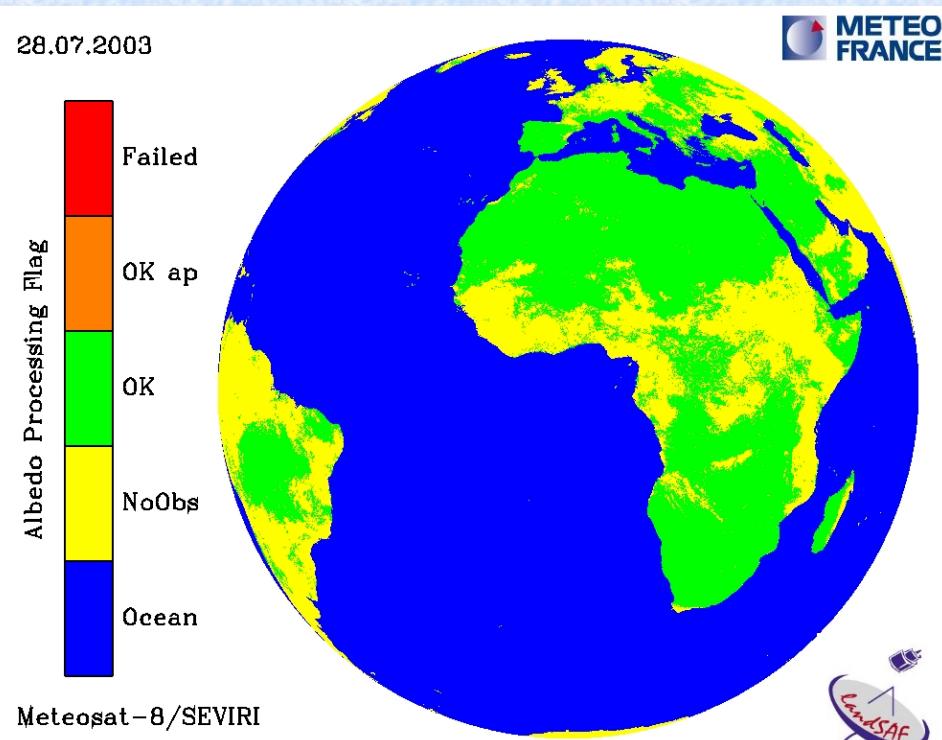
(1.63 - 1.65 μ m)



Error Estimate

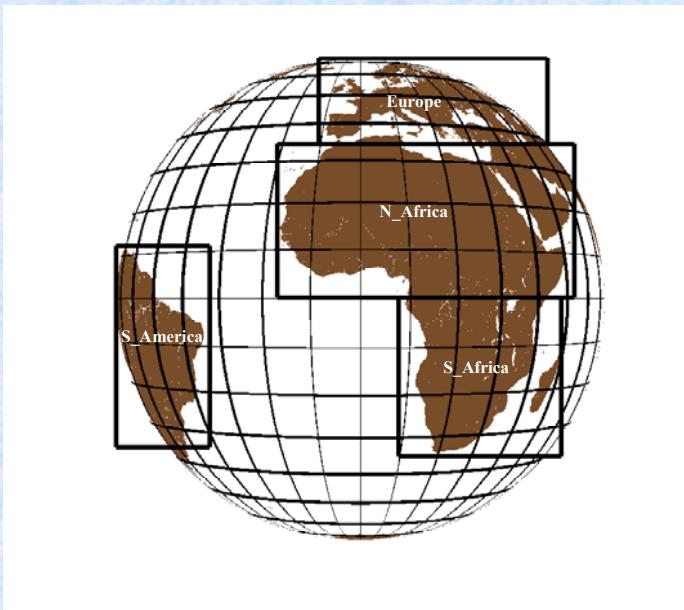


Quality Flag

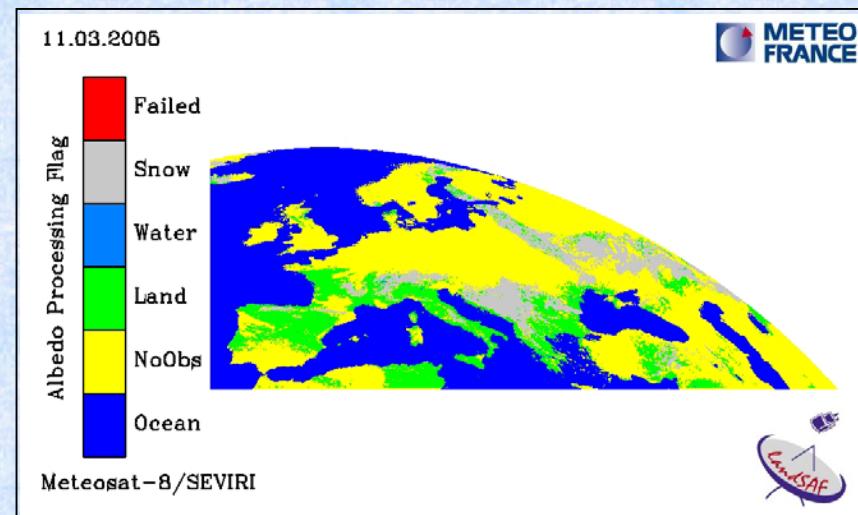
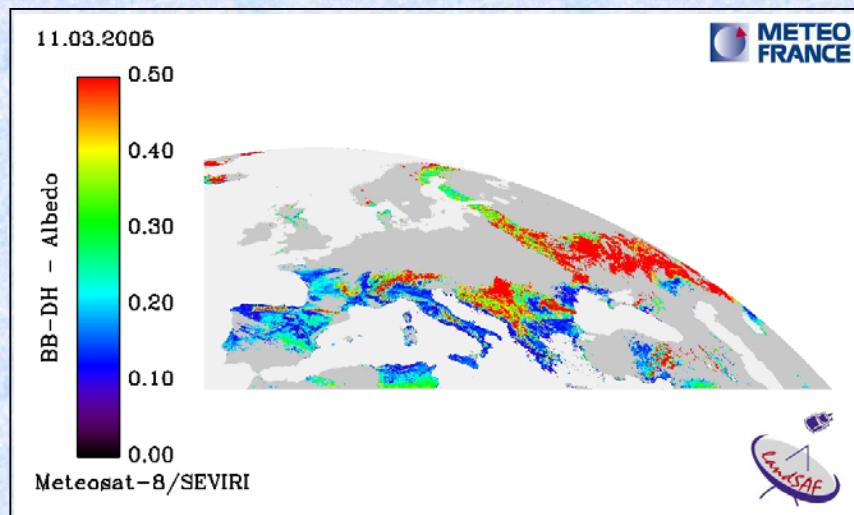
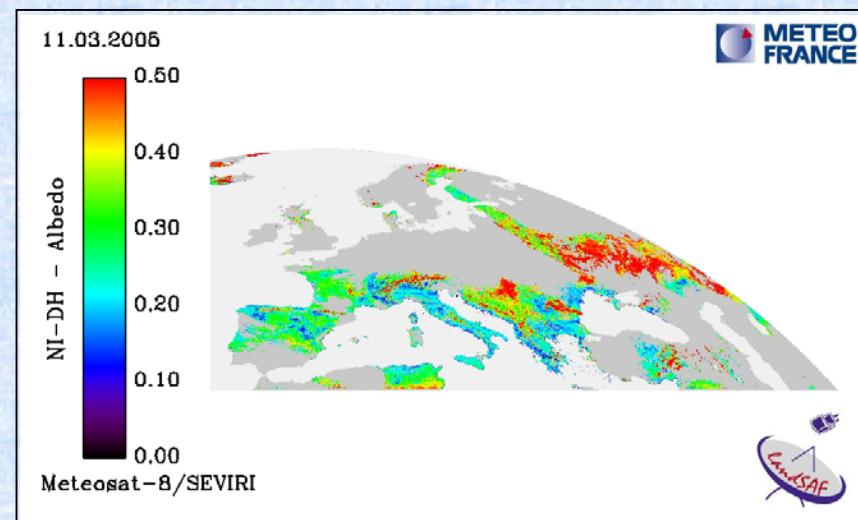
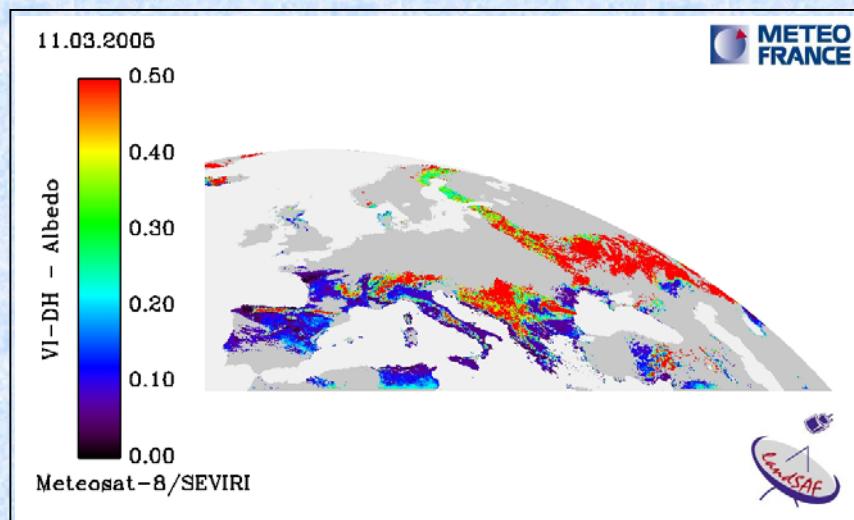


Synopsis of the Land SAF albedo operational product

- Europe, N_Africa, S_Africa, S_America
- pixel by pixel basis
- MSG full resolution (3km×3km at nadir)
- SEVIRI instrument projection
- Units : Dimensionless
- Range: 0 - 1
- Accuracy: 10%
- Format: 16 bits signed integer
- 8 bits (quality flag)
- Frequency of Generation: daily



Examples of SAF Land (MSG) image products on March 11, 2005.



(from B.Geiger)

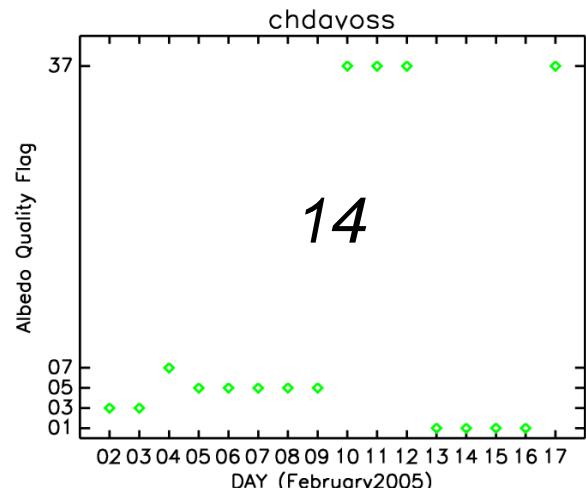
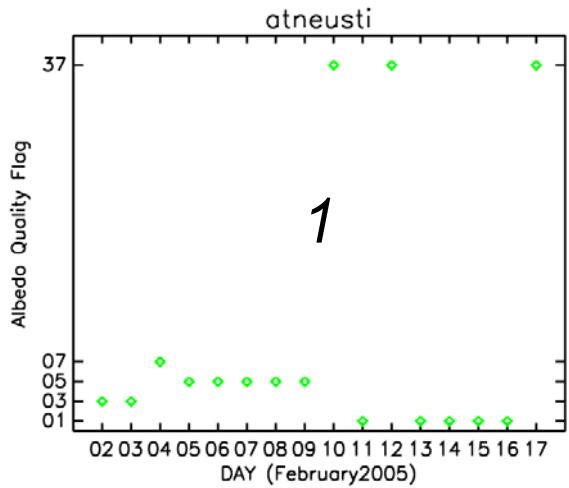
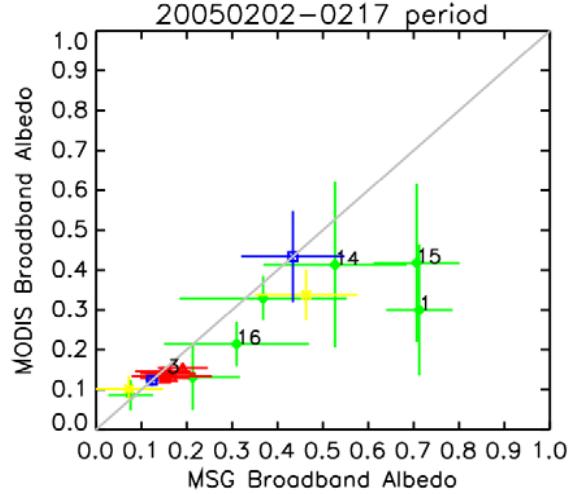
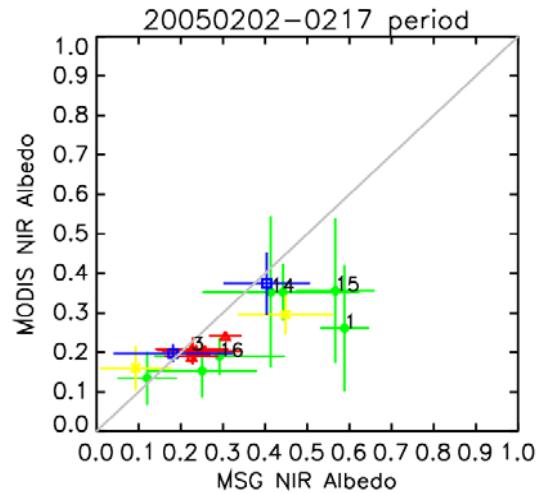
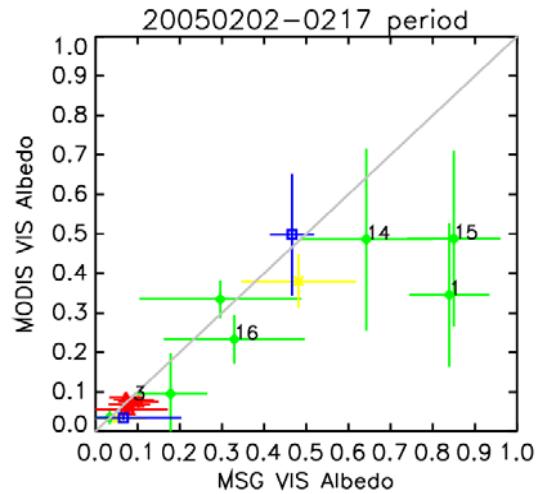
Comparison between MODIS & MSG albedo products

List of selected sites amongst available MODIS ASCII subsets

Site	Site	<i>latitude</i>	<i>longitude</i>	Vegetation type	Altitude (m)	
ID	Name				DEM	site info.
1	atneusti	47.112500	11.320317	Evergreen needleleaf forest	1208	970
2	frpuecha	43.737500	03.592775	Mixed forest	229	250-270
3	itnonant	44.687500	11.082544	Cropland/Natural vegetation	11	25
4	itnovara	44.795833	08.425848	Cropland/Natural vegetation	145	No data
5	itpovall	44.787500	08.119348	Cropland/Natural vegetation	185	No data
6	itcanara	45.204167	09.077478	Cropland/Natural vegetation	70	65
7	itsanros	43.729167	10.292474	Evergreen needleleaf forest	2	No data
8	itrocca2	42.404167	11.934486	Cropland/Natural vegetation	162	No data
9	itlavaro	45.954167	11.285176	Evergreen needleleaf forest	941	1371
10	itcastel	41.704167	12.372925	Evergreen broadleaf forest	12	3
11	itroccal	42.387500	11.920035	Cropland/Natural vegetation	159	142
12	ptevora	38.537500	-07.995605	Cropland/Natural vegetation	228	220-250
13	chpayern	46.812500	06.946595	Evergreen broadleaf forest	553	No data
14	chdavoss	46.820833	09.858265	Evergreen needleleaf forest	1761	1640
15	chsehorn	46.812500	09.856737	Evergreen needleleaf forest	1925	No data
16	czbilykr	49.504167	18.536548	Evergreen needleleaf forest	794	898
17	eetorave	58.254167	26.457813	Mixed forest	57	No data
18	fikaaman	69.137500	27.296013	Evergreen needleleaf forest	167	155
19	fisodank	67.362500	26.641155	Evergreen needleleaf forest	201	180
20	seflakal	64.112500	19.458831	Evergreen needleleaf forest	244	226

02 - 17 feb. 2005

- ◊ ◊ Evergreen needleleaf forest
- × × Evergreen broadleaf forest
- △ △ Cropland/Natural vegetation
- □ Mixed forest



MSG Albedo product quality flag:

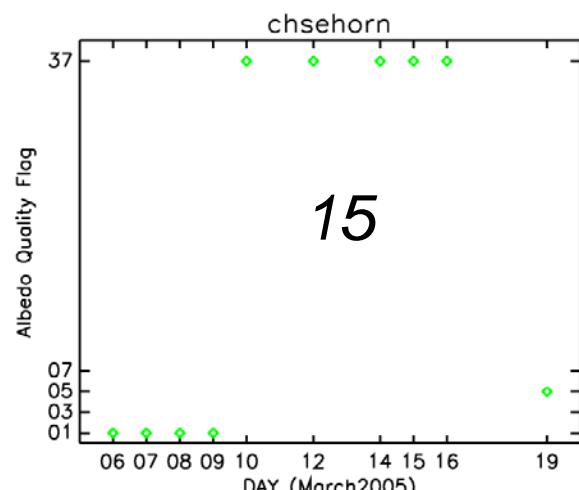
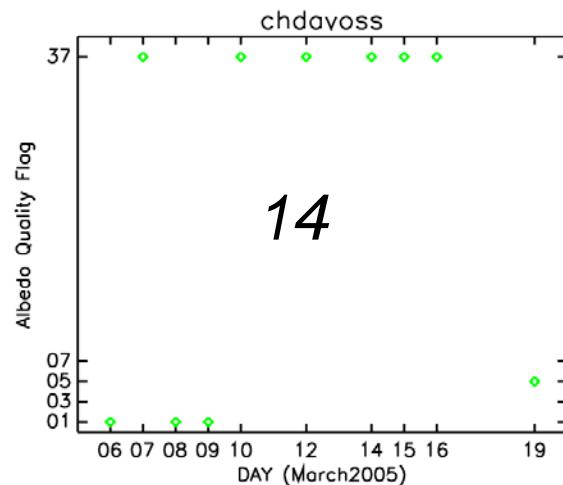
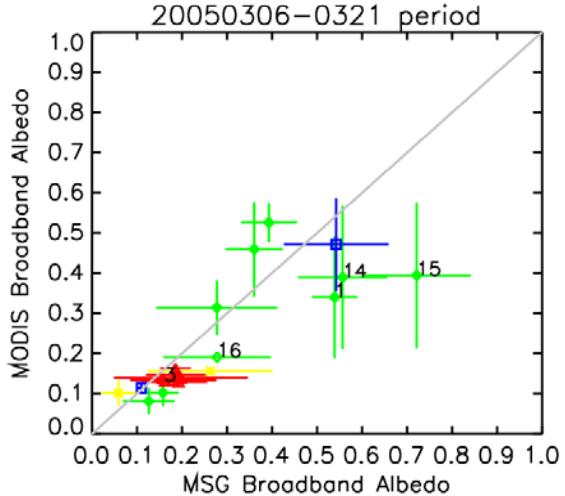
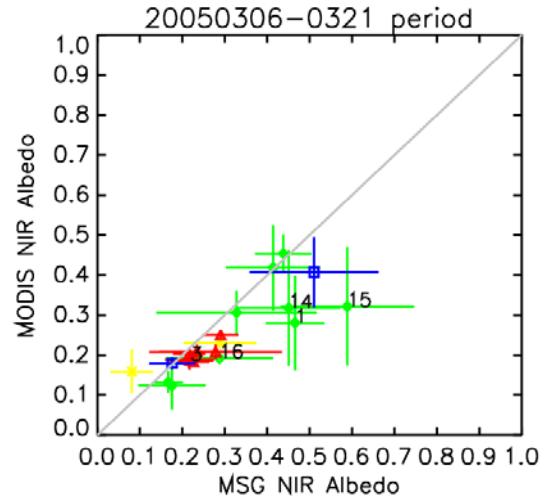
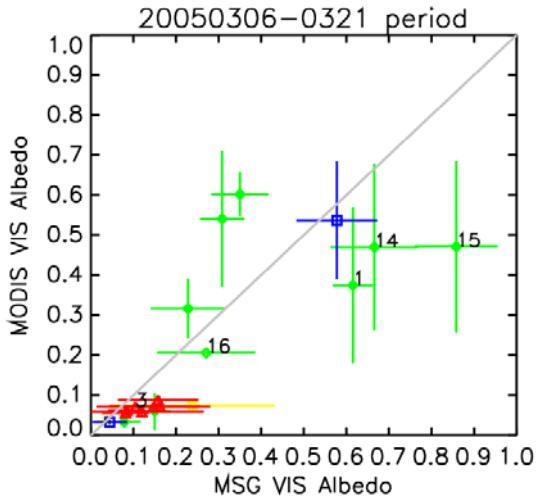
- | | |
|----|------------------------------------|
| 01 | No MSG observations (Land) |
| 03 | No MSG observations (inland water) |
| 05 | MSG observations (Land) |
| 07 | MSG observations (inland water) |
| 37 | Snow |

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(from S.Lanjeri)

06 - 21 march 2005

- ◆ ◆ Evergreen needleleaf forest
- ✗ ✗ Evergreen broadleaf forest
- △ △ Cropland/Natural vegetation
- □ Mixed forest



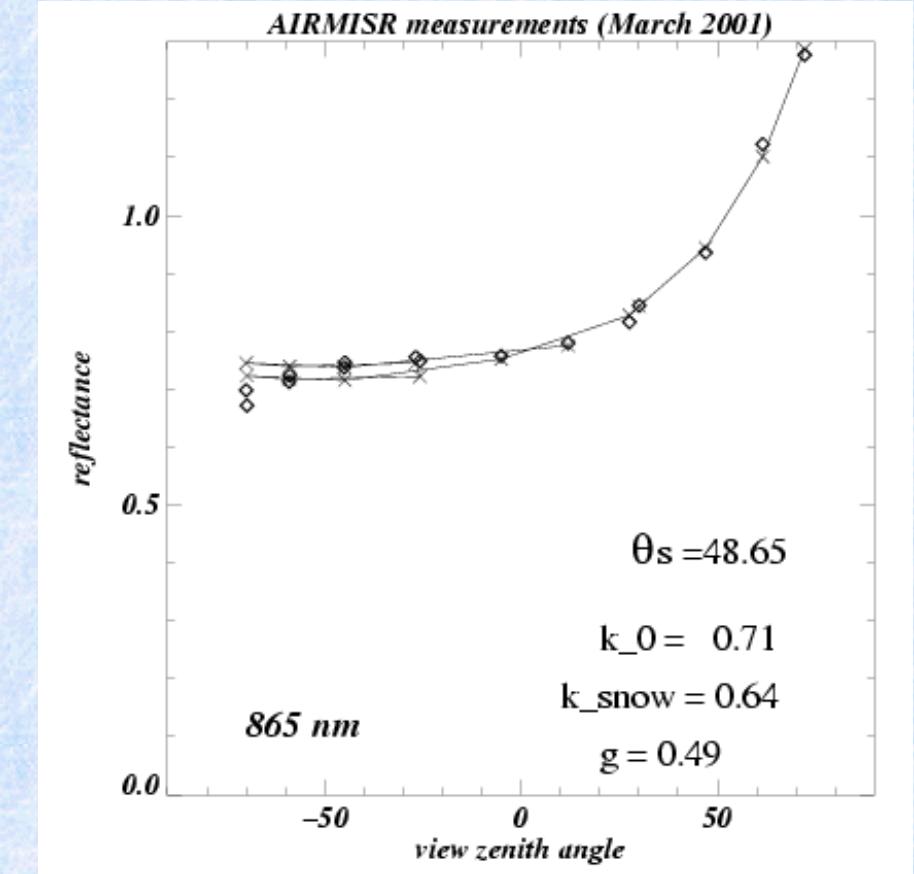
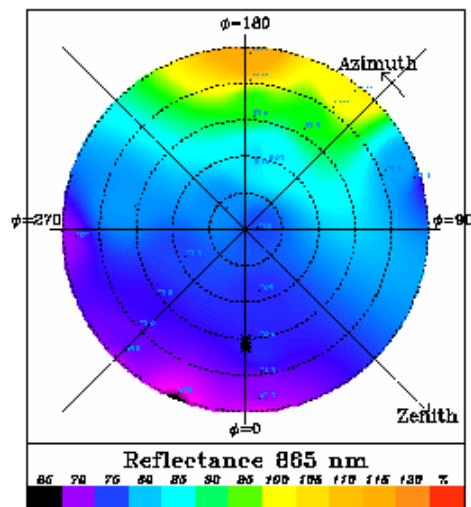
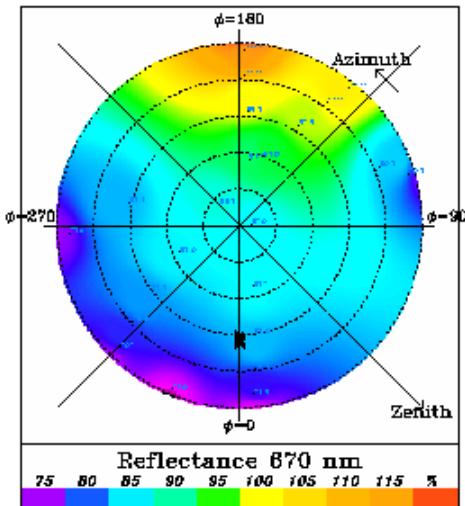
MSG Albedo product quality flag:

- 01 No MSG observations (Land)
- 03 No MSG observations (inland water)
- 05 MSG observations (Land)
- 07 MSG observations (inland water)
- 37 Snow

(from S.Lanjeri)

AirMISR BRDF over snow targets (Steam Boat, Colorado)

Snow/Ice (AIRMISR) , March 8, 2001



(Symbols) **AirMISR measurements**

(solid line) **simulations from BRDF model**

$$\rho(\theta_s, \theta_v, \phi) = k_0 + k_{\text{snow}} \cdot f_{\text{snow}}(\theta_s, \theta_v, \phi)$$



VALIDATION PLAN



WP 1. Intercomparison with similar spatially distributed products

Statistical analysis (error bar, bias, standard deviation) between co-registered MODIS and MSG/CYCLOPES/POLDER images for the 3 broadband albedos (visible, NIR, total) [topography, clouds, aerosols, sub-pixel variability]

WP2. In situ measurements from sites BSRN

Data processing for selected sites (speed-up communication with site captains, statistical analysis, coordination with MODLAND)

High resolution imagery (Landsat, SPOT, MODIS at 250 m) for 2 or 3 BSRN stations to asses the degree of homogeneity (<clumping indices) → strategy to be defined

WP3. Field campaigns

SNORTEX: Seasonal variability of snow/vegetation BRDF in Lapland with airborne POLDER
(coll. Finnish Meteorological Institute)

Comparison with BRDF from NOAA/AVHRR et other sensors (MODIS, MISR, POLDER, VGT)



Short-term scheduled activities (high priority !)

- Resolve known technical issues plus improve cloud mask (Land SAF)
- Inter-calibrate sensors (VGT & AVHRR), improve cloud mask, aerosol correction (CYCLOPES)
- Broadband Albedos : tuning of theoretical values of conversion coefficients with real data sets (→ precision < 10 %)
- Filling missing data : use of Kalman filter and/or land cover map
- Snow Albedo : use of snow kernel proposed by *Roujean and Stroeve* (JAM, 2005)
- Systematic comparison with MODIS albedos (down-link with DAAC)